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TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

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No. 111.

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STRESSES PRODUCED ON AN AIRSHIP FLYING THROUGH GUSTY AIR.

By Max M. Munk.

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September, 1922.

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STRESSES PRODUCED ON AN AIRSHIP FLYING THROUGH GUSTY AIR.

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Summary.

The stresses produced by gusts are proportional to the speed of the airship. At highest speed they are of the same range of magnitude as the stresses during the creation of a large dynamic lift.

References.

1. Munk: Notes on aerodynamic forces. N.A.C.A. Technical Notes 104 to 106, July, 1922.
2. Dr. W. N. Shaw: Report on vertical motion in the atmosphere. B.A.C.A. 1909/10.
3. J. S. Dines: Fourth report on wind structures. B.A.C.A. 1912/13.

Most airship pilots are of opinion that severe aerodynamic forces act on airships flying in bumpy weather. An exact computation of the magnitude of these forces is not possible as they depend on the strength and shape of the gusts and as probably no two exactly equal gusts occur. Nevertheless, it is worth while to reflect on this phenomenon and to get acquainted with the underlying general mechanical principles. It will be possible to determine

how the magnitude of the velocity of flight influences the air forces due to gusts. It even becomes possible to estimate the magnitude of the air forces to be expected, though this estimation will necessarily be somewhat vague, due to ignorance of the gusts.

The airship is supposed to fly not through still air but through an atmosphere the different portions of which have velocities relative to each other. This is the cause of the air forces in bumpy weather, the airship coming in contact with portions of air having different velocities. Hence, the configuration of the air flow around each portion of the airship is changing as it always has to conform to the changing relative velocity between the portion of the airship and the surrounding air. A change of the air forces produced is the consequence.

Even an airship at rest experiences aerodynamical forces in bumpy weather, as the air moves towards it. This is very pronounced near the ground where the shape of the surrounding objects gives rise to violent local motions of the air. The pilots have the impression that at greater altitudes an airship at rest does not experience noticeable air forces in bumpy weather. This is plausible. The hull is struck by portions of air with relatively small velocity, and as the forces vary as the square of the velocity they cannot become large.

It will readily be seen that the moving airship cannot experience considerable air forces if the disturbing air velocity is in the direction of flight. Only a comparatively small portion of the

air can move with a horizontal velocity relative to the surrounding air and this velocity can only be small. The effect can only be an air force parallel to the axis of the ship which is not likely to create large structural stresses.

There remains then as the main problem the airship in motion coming in contact with air moving in a transverse direction relative to the air surrounding it a moment before. The stresses produced are severer if a larger portion of air moves with that relative velocity. It is therefore logical to consider portions of air large when compared with the diameter of the airship; smaller gusts produce smaller air forces. It is now essential to realize that their effect is exactly the same as if the angle of attack of a portion of the airship is changed. The air force acting on each portion of the airship depends on the relative velocity between this portion and the surrounding air. A relative transverse velocity  $u$  means an effective angle of attack of that portion equal to  $u/V$ , where  $V$  denotes the velocity of flight. The airship therefore is now to be considered as having a variable effective angle of attack along its axis. The magnitude of the supposed angle of attack is  $u/V$  where  $u$  generally is variable. The air force produced at each portion of the airship is the same as the air force at that portion if the entire airship would have that particular angle of attack.

The magnitude of the air force depends on the conicity of the airship portion as described in former notes (reference 1). The force is proportional to the angle of attack and to the square of

the velocity of flight. In this case however the superposed part of the angle of attack varies inversely as the velocity of flight. It results then that the air forces created by gusts are directly proportional to the velocity of flight. Indeed, as I have shown in the notes mentioned, they are proportional to the product of the velocity of flight and the transverse velocity relative to the surrounding air.

A special and simple case to consider for a closer investigation is the problem of an airship immersing from air at rest into air with constant transverse horizontal or vertical velocity. The portion of the ship already immersed has an angle of attack increased by the constant amount  $u/V$ . Either it can be assumed that by operation of the controls the airship keeps its course or, better, the motion of an airship with fixed controls and the air forces acting on it under these conditions can be investigated. As the fins come under the influence of the increased transverse velocity later than the other parts, the airship is as it were unstable during the time of immersing into the air of greater transverse velocity and the motion of the airship aggravates the stresses.

In spite of this the actual stresses will be of the same range of magnitude as if the airship flies under an angle of pitch of the magnitude  $u/V$ , for in general the change from smaller to greater transverse velocity will not be so sudden and complete as supposed in the last paragraph. It is necessary chiefly to investigate the case of a vertical transverse relative velocity  $u$ , for

the severest condition for the airship is a considerable angle of pitch, and a vertical velocity  $u$  increases these stresses. Hence it would be extremely important to know the maximum value of this vertical velocity. The velocity in question is not the greatest vertical velocity of portions of the atmosphere occurring, but differences of this velocity within distances smaller than the length of the airship. It is very difficult to make a positive statement as to this velocity, but it is necessary to conceive an idea of its magnitude, subject to a correction after the question is closer studied. Studying the meteorological papers in the Reports of the British A.C.A., chiefly those of 1909/10 and 1912/13, I should venture to consider a sudden change of the vertical velocity by 2 m/s (6 1/2 ft/s) as coming near to what to expect in very bumpy weather. The maximum dynamic lift of an airship is produced at low velocity, and is the same as if produced at high velocity at a comparatively low angle of attack, not more than  $5^\circ$ . If the highest velocity is 30 m/s (67 m/h) the angle of attack  $u/V$  repeatedly mentioned before would be  $\frac{57.3 \cdot 2}{30} = 3.8^\circ$ . That is a little smaller than  $5^\circ$  but the assumption for  $u$  is rather vague. It can only be said that the stresses due to gusts are of the same range of magnitude as the stresses due to pitch, but they are probably not larger.

A method for keeping the stresses down in bumpy weather is by slowing down the speed of the airship. This is a practice common among experienced airship pilots. This procedure is particularly recommended if the airship is developing large dynamic lift, positive or negative, as then the stresses are already large.